LOAN DOCUMENT

PHOTOGRAPH THIS SHEET

AD-A237 280

DTIC ACCESSION NUMBER

LEVEL

INVENTORY 1

WRDC-TR-89-8038 Vol. I

DOCUMENT IDENTIFICATION

Sept 1989

DISTRIBUTION STATEMENT A

Approved for public release;
Distribution Unlimited

DISTRIBUTION STATEMENT

H A N D L E W I T H C A R E

ACCESSION FOR

NTIS GRA&I ☒
DTIC TRAC ☐
UNANNOUNCED ☐
JUSTIFICATION

BY

DISTRIBUTION/

AVAILABILITY CODES

DISTRIBUTION	AVAILABILITY AND/OR SPECIAL	
A-1		

DISTRIBUTION STAMP

DTIC
ELECTE
JUN 27 1991
S E D

DATE ACCESSIONED

DATE RETURNED

91-02817

2

DATE RECEIVED IN DTIC

REGISTERED OR CERTIFIED NUMBER

PHOTOGRAPH THIS SHEET AND RETURN TO DTIC-FDAC

DTIC FORM JUN 90 70A

DOCUMENT PROCESSING SHEET

PREVIOUS EDITIONS MAY BE USED UNTIL STOCK IS EXHAUSTED

LOAN DOCUMENT

AD-A237 280

WRDC-TR-89-8038 (Volume I)

GEOMETRIC MODELING APPLICATIONS INTERFACE PROGRAM (GMAP)

UNITED TECHNOLOGIES CORPORATION
Pratt & Whitney
Government Engine Business
West Palm Beach, Florida 33410-9600

September 1989

FINAL REPORT for the Period August 1985 — March 1989
Volume I — Executive Overview

PREPARED FOR:

MANUFACTURING TECHNOLOGY DIRECTORATE
WRIGHT RESEARCH & DEVELOPMENT CENTER
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433-6533

NOTICES

This technical report has been reviewed and is approved for publication.

Charles R. Gilman

Charles Gilman
Project Manager

9-15-89
Date

FOR THE COMMANDER:

Walter H. Reimann, Chief
Computer-Integrated Mfg. Branch

9-15-89
Date

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY 2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	3. DISTRIBUTION/AVAILABILITY OF REPORT APPROVED FOR PUBLIC RELEASE DISTRIBUTION UNLIMITED
4. PERFORMING ORGANIZATION REPORT NUMBER(S) FR 20802	5. MONITORING ORGANIZATION REPORT NUMBER(S) WRDC-TR-89-8038 Volume I
6a. NAME OF PERFORMING ORGANIZATION United Technologies Corporation Pratt & Whitney Government Products Division 6b. OFFICE SYMBOL (If applicable) (P&W)	7a. NAME OF MONITORING ORGANIZATION Manufacturing Technology Directorate (WRDC/MLTC) Wright Research and Development Center
6c. ADDRESS (City, State and ZIP Code) P.O. Box 9600 West Palm Beach, Florida 33410-9600	7b. ADDRESS (City, State and ZIP Code) Wright-Patterson Air Force Base, OH 45433-6533
8a. NAME OF FUNDING/SPONSORING ORGANIZATION 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER F33615-85-C-5122
8c. ADDRESS (City, State and ZIP Code)	10. SOURCE OF FUNDING NOS.

11. TITLE (Include Security Classification)	PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT NO.
GEOMETRIC MODELING APPLICATIONS INTERFACE PROGRAM (GMAP)	78011F0	MTPI	06	74

12. PERSONAL AUTHOR(S)
L. Phillips, K. Perlotto, D. Koziol Emmerson, P. Blasko, D. Jacobs, R. Disa, J. Wright

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Yr., Mo., Day)	15. PAGE COUNT
Final	FROM 1 Aug 85 TO 31 Mar 89	1989 SEPTEMBER	24

16. SUPPLEMENTARY NOTATION
Subject to Export Control Law

17. COSATI CODES		
FIELD	GROUP	SUB. GR.

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
Geometric Modeling Applications Interface Program
Product Definition Data Interface
Turbine Blades and Disks

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This first Volume of the Final Technical Report describes the significance and presents a high level overview of the Geometric Modeling Applications Interface Program (GMAP), conducted under U.S. Air Force Contract F33615-85-C-5122. The GMAP Program focused on the computerized generation, control, and exchange of traditional engineering design and manufacturing data. GMAP extended the Product Definition Data Interface Program (PDDI) information model to include computerized support applications for the entire life cycle of a product. GMAP specifically applied product life-cycle support, including engineering, manufacture, inspection, and logistics support, to cooled jet engine turbine blades and disks.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT UNCLASSIFIED/UNLIMITED X SAME AS RPT. __ DTIC USERS __	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED	
22a. NAME OF RESPONSIBLE INDIVIDUAL Mr. Charles Gilman	22b. TELEPHONE NUMBER (Include Area Code) (513) 255-7371	22c. OFFICE SYMBOL WRDC/MLTC

DD FORM 1473, 83 APR   EDITION OF 1 JAN 73 IS OBSOLETE.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

FOREWORD

This first volume of the Final Technical Report describes the significance and presents a high level overview of Air Force Contract F33615-85-C-5122, Geometric Modeling Applications Interface Program (GMAP), covering the period 1 August 1985 to 31 March 1989. The contract was sponsored by the Manufacturing Technology Directorate, Wright Research & Development Center, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio, 45433-6533. This program was administered under the technical direction of Mr. Charles R. Gilman.

The primary contractor was Pratt & Whitney, an operating unit of United Technologies Corporation (UTC). Pratt & Whitney engaged several additional firms as subcontractors, including United Technologies Research Center (UTRC), McDonnell Aircraft Company (MCAIR), and International TechneGroup Incorporated (ITI), to assist in various tasks of the program. At Pratt & Whitney, the program was managed by Mr. Richard Lopatka. Ms. Linda Phillips was the Program Integrator, and Mr. John Hamill was the Deputy Program Manager.

Note: The number and date in the upper right corner of each page of this document indicate that the volume has been prepared according to the ICAM CM Life Cycle Documentation requirements for a Configuration Item (CI).

TABLE OF CONTENTS

LIST OF TABLES

R20602/17

SECTION 1

INTRODUCTION

1.1 DOCUMENT FOCUS

This Executive Overview volume of the GMAP Final Report is aimed at the management level of industry and Government. The document's sole purpose is to provide a high level summary of the GMAP work and relay the significance of the results to both industry and the Government to assist them in determining the appropriate next steps to be taken.

1.2 PROGRAM FOCUS

The primary focus of GMAP was the generation, control, and exchange of computerized product model information that will replace traditional design and manufacturing drawings. This product model information is referred to as Product Definition Data (PDD) throughout the GMAP documents.

The requirement for GMAP stemmed from the increasing use of geometric modeler-based software systems in aerospace product life cycle operations. There was a need to share information produced by these systems in an efficient and cost-effective manner. Today, it is becoming more important for major manufacturers to be able to share computerized product information with nearly all internal product life cycle operations, as well as with partners, suppliers, and customers. This product information goes beyond the geometric modeler-based data that are readily available from the Computer Aided Design (Drafting) and Computer Aided Manufacturing (CAD/CAM) systems in use.

1.3 BACKGROUND

The need for a means to exchange PDD began in the late 1970s with the growth of minicomputer-based CAD/CAM systems. Since then, several initiatives have been undertaken that deal with the problems of data exchange among the different CAD/CAM hardware and software platforms. The Initial Graphics Exchange Specification (IGES) is the most well known of these initiatives.

1.3.1 Product Definition Data Interface

In 1982, the Air Force funded the Product Definition Data Interface (PDDI) program to determine the feasibility of using computerized PDD as the primary means of communicating engineering information to manufacturing. This program had two main tasks: (1) to evaluate and verify the then current standard, ASME/ANSI Y14.26M-1981 (sometimes referred to as IGES Version 1.0) for PDD exchange and (2) using the results of the first task, demonstrate a prototype system that integrates engineering and manufacturing using the electronic equivalent of a blueprint.

The results of the PDDI program were quite significant. In fact, the results were instrumental in starting several large-scale initiatives within both industry and the DoD. The major findings of PDDI Task I were:

- IGES was capable of representing computer-aided drafting models, but could not support the informational needs of manufacturing.

- IGES translators were less adequate than expected with respect to completeness and correctness of translation.

Based on the Task I findings, PDDI Task II was initiated to build a prototype system that could support the informational needs of manufacturing. This would be accomplished by providing an interface "system" between engineering and manufacturing. This interface "system" was successfully demonstrated and discussed at the PDDI end-of-contract executive debriefing held in September 1985. During the PDDI efforts, sufficient industry interest was generated in 1984 to initiate the PDES task within the National Bureau of Standards' IGES organization. At the same time, the United States joined forces with other countries, through the International Standards Organization (ISO), to develop a single worldwide standard for the exchange of product data. The goal of these efforts is "...the capture of information comprising a computerized product model in a neutral form...throughout the life cycle of the product."

1.3.2 Role of GMAP

To get a better understanding of the informational needs for computerized product data throughout the life cycle of a product, the Air Force funded the Geometric Modeling Applications Interface Program (GMAP) as a follow-on to the PDDI program. Using the PDDI system as a baseline, GMAP further developed an architecture for data exchange.

GMAP focused on the development of a specification for complete PDD. Demonstrations were conducted to show that this information could be communicated via a computer PDD part model to numerous life cycle applications within Pratt & Whitney, at supplier facilities, and within Air Force Logistic Centers. Further, it demonstrated the ability to share this information across a variety of computer and software platforms.

During GMAP (1985-1989), several events took place which resulted in GMAP achieving more positive results then originally anticipated.

First, in September 1985, the Deputy Secretary of Defense launched the Computer-aided Acquisition and Logistics Support (CALS) program. The various DoD agency thrusts in the area of digital data exchange were focused through the establishment, in October 1986, of the CALS Policy Office by the Under Secretary of Defense for Acquisition. The responsibility of this office was to guide the development and implementation of CALS data exchange standards, advocate their integration into military information systems and weapon acquisition programs, and provide a single DoD interface to industry on CALS data exchange. GMAP was designated a CALS system integration and architecture program in 1986.

Second was the establishment, in April 1988, of PDES, Inc., a joint industry and Government effort to accelerate the development, validation, and implementation of the Product Data Exchange Specification (PDES). This 36-month program consists of two phases. Phase I focuses on validation and implementation of a subset of the PDES submitted to ISO as a draft standard. The emphasis of this work is on data exchange. Phase II will switch the focus from exchange to integration of data and will broaden the PDES subsets to include electronic parts. The results of GMAP are anticipated to be useful to this group by assisting them in building models for testing and validation of PDES and by supplying an architecture for implementation.

Third was the reorganization of the National Bureau of Standards into NIST, the National Institute for Standards and Technology, and the establishment of a National PDES testbed. The GMAP/PDDI software components and architecture concepts were adopted in June 1989 to form the baseline system for the development of the structure needed to support the National testbed.

The GMAP system software installed at NIST is being made available to industry to test the evolving PDES specification. Testing PDES in the GMAP environment includes the creation of product model instances in the PDES information structure, and the development and evaluation of application programs against those product models. The tools with which this can be accomplished are part of the GMAP system architecture. The GMAP system at NIST, along with the provided PDES physical implementation files, supports every entity in the PDES specification. Presently, it is believed to be the only facility available to general industry that can make this claim. As such, the interest in this environment should continue to be very high.

Furthermore, with minimal effort, the PDES specification upon which the system operates can be replaced with future versions of the PDES specification using the data independence of the GMAP system architecture.

SECTION 2

SCOPE OF GMAP

GMAP focused on the generation, control, and exchange of computer information to replace traditional design and manufacturing drawings. The goal was to improve communication between aerospace prime contractors and their partners, multiple tiers of subcontractors, military and commercial users of aerospace products, and supporting agencies. In performing the tasks associated with the program, several issues that the Air Force had identified were addressed. These issues are outlined below.

2.1 DESIRE FOR DIGITAL DATA

Both the GMAP and the PDDI programs were undertaken by the Air Force as part of their attempt to deal with their problem of paper drawings and the communication of engineering data. While a single company may have millions of drawings, the Air Force has billions! The efforts relating to the use and maintenance of the paper drawings that are stored in the data repositories were, and still are, a massive and very expensive problem. The Air Force, as well as the other military services, looked for some time to find alternative approaches. As several initiatives were undertaken in the late 1970s and early 1980s to deal with the paper through the use of raster technology, the Air Force began to take a harder look at the need, communication, and use of this engineering data. They found that although paper drawings serve a useful purpose, the real need, and potentially higher cost savings, was found to be in the ability to communicate the engineering data in intelligent computerized form. One of the first expectations for GMAP was that we would be able to completely replace the existing paper documents with computerized data.

2.2 EXPAND FOCUS TO LOGISTICS

Most of the PDD research prior to GMAP was on the informational needs of manufacturing. The Air Force wanted to factor in the informational needs of Logistics Support. Part of the Air Force's modernizations efforts was to introduce automation into the Logistic Centers. In moving from manual to automated inspection systems, the Air Force found that there was a need to build interfaces to these systems so that they could access the computerized data instead of manually re-entering this information. They felt that this would reduce lead time, reduce input errors, and improve accuracy. The Air Force hoped that GMAP would provide an interface to two existing functional applications: IBIS (Integrated Blade Inspection System) and RFC (Retirement for Cause). Both of these systems were highly automated but required a lengthy lead time to reproduce the part models from the paper drawings. It was felt that the cost of creating the scan plans could be greatly reduced by applying GMAP interfaces to these systems.

2.3 GEOMETRIC MODELING DISCONNECTS

Geometric modelers in current product life cycle applications use a number of different techniques to create, represent, and manipulate PDD. The most mature of these systems can be classified into three general categories: wireframe, surface, and solid. More recently, two additional categories have developed: feature-based and object oriented. Communicating information between these systems results in a loss of information and is very difficult because there are disconnects in the kind of data and the relationships between the data. It was expected that GMAP would investigate approaches to minimize the movement of data and develop a method for allowing this communication without data loss. A method to share data in an integrated environment was anticipated.

2.4 INCOMPLETE PDD

When the Air Force began the PDDI program in 1982, most CAD/CAM systems were still based on the philosophy that the end result was to produce a paper drawing. These systems all supported the ability to create, manipulate, and communicate geometric and annotation information. However, most could not support the data that was being defined by PDDI (and GMAP) as being necessary to build complete part models. This information included administrative, assembly, topology, feature, tolerance, and nonshape data. It was anticipated that the GMAP project would develop a complete specification for this information and develop a prototype means to build the part models.

2.5 UNREACHABLE DOWNSTREAM APPLICATIONS

It has often been said that manufacturing does not use the information supplied by engineering because the data are not in the desired format and, more often than not, they are not the information required. Basically, the problem is due to the way each of the life cycle groups view the part and their need for the information. An engineer, for example, might look at a workpiece with a hole in it and see stress problems; a manufacturer looking at the same workpiece and the same hole could see drilling procedures. Since engineering is the creator of the information, they normally create only the information that they require. Thus, the downstream applications, manufacturing and support, which are in need of supplemental information, are not satisfied. It was anticipated that the GMAP project would provide a detailed analysis of the life cycle information needs and help define the requirements of a modeling system to satisfy these needs.

SECTION 3

MAJOR PROGRAM ACCOMPLISHMENTS

The successful completion of GMAP can be measured by the accomplishments achieved in satisfying the goals and objectives of GMAP. The major accomplishments are described below.

3.1 COMPLETE REPRESENTATION IN DIGITAL FORM

Prior to the GMAP effort, the computerization of all information needed to support a product throughout its lifecycle had not been studied in detail. GMAP successfully conducted a thorough investigation on such information for turbine blades and disks. These parts were selected because:

- They had a wide range of simple and complex geometries (defined, undefined, internal, and external surfaces).
- They provided a vehicle to determine the nongeometric information that is required, but not normally conveyed, electronically with the geometric information.

It was believed that if the information associated with these parts could be identified and organized, then it was possible to do the same for any part family. The result of this effort was that an information structure, or schema, was created that was capable of supporting the data needs of the applications throughout the lifecycle.

In the process of studying these data, it was determined that they could be categorized into distinct data classes: Administrative, Assembly, Tolerance, Nonshape, Topology, Form Features, and Geometry. Most of the work involved in categorizing was in understanding how the applications used the data. Once that was done, information diagrams were constructed using information modeling techniques. These diagrams created a visual record of the information needs.

The actual integration process involved organizing the data classes into one integrated model. There was some difficulty in relating the nonshape information (Administrative, Assembly, Tolerance, and Nonshape) with the physical shape of the part. This resulted in developing an additional class, the Shape data class. In relating the findings to the PDES community, it was recommended that PDES be organized along the concept of the Shape data class. The PDES organization adopted this approach in 1988.

As complete models of the GMAP parts were developed, limits that exist within the current implementations of today's CAD/CAM systems were encountered. These limits were such things as available computer memory, number of allowable entities, and database relationships. For example, it was discovered that complete PDD part models were significantly larger than the current CAD/CAM part models. Also, in building the solid model of the turbine blade, we were restricted by the number of facets in a solid, which prohibited the addition of much of the "small" geometric entities, such as fillets, trip strips, and cooling holes. We could not put all of the fillets in the model, and some of the boolean operations would not execute as expected.

Further, we observed that the addition of the nongeometric PDD only encompassed 2 percent of the total model size. This is not true of the disk model built for GMAP, where nongeometric information encompassed 73 percent of the total model. We estimated that a complete model of a GMAP turbine blade would require approximately 80 megabytes of disk storage. Until the above mentioned limitations can be dealt with, they will constrain the development of complete part models.

3.2 DEMONSTRATED PDD EXCHANGE

Once the analysis of the information needed to support the life cycle was completed, it was necessary to test the findings and demonstrate the results. To demonstrate success throughout the total life cycle, a sampling of applications that represented a rigorous cross section of the life cycle was selected for demonstration. Our criteria for selection was based on problem-solving techniques used by Pratt & Whitney's internal Q+ process. This resulted in our using five basic questions to review the applications for selection:

1. How important is this application to the full life cycle coverage of turbine blades and disks?

2. What is the breadth of the functional application in the full life cycle coverage?

3. What is the depth of the functional application in terms of producing or consuming PDD?

4. If this application is supported, how much enhancement or advancement (in the use of PDD) will be enabled?

5. Does the application meet the requirements of the GMAP contract?

Potential functional application areas were evaluated based on the above criteria. Seventeen key functional applications were identified by the GMAP team. These were reviewed with the Air Force and the GMAP Industry Review Board (IRB). Thirteen were finally selected for demonstration and are identified in Table 3-1.

During the selection process, it was discovered that few existing applications existed that could use the nongeometric PDD. A 3-D N/C and CMM programming application (item 9 in Table 3-1) was developed to demonstrate the use of form features and nonshape information to automate the generation of N/C programs and CMM programs.

Three video tapes were created to document the GMAP demonstrations. There is one on the disk life cycle, one on the blade life cycle, and a third focusing on an engine case plumbing attachment boss. The two life cycle video tapes show how the data exchange and the applications can be improved by having complete PDD part models available. The case boss video tape was created to illustrate a part more typical of industry outside of aerospace.

TABLE 3-1.

SELECTED DEMONSTRATION APPLICATIONS

1. Detailed Blade and Disk Design and Analysis
   Final Blade and Disk Design and Analysis
   (Detailed and final blade and disk design and analysis are grouped together because of common applications.)
   a) Parametric cooled turbine blade and disk design (includes core and cooling holes)
   b) Design Verification and Analysis
   c) Aerodynamic Design Surface Verification
2. Detailed Engineering Specifications
   a) Nonshape and tolerance PDD creation
3. Quality Requirements Engineering
) PROcess CAPability (PROCAP)
4. Categorize and Review Parts/Processes
5. General Process Planning
   a) Data feed to computer-aided process planning
6. Casting Process Planning
   a) Airfoil casting simulation using finite element analysis (feature based solid model)
7. Numerical Control (N/C) Programming for Airfoil Casting Molds and Dies and Tool Design
8. Disk Forging
9. N/C Programming — Disk Machining
   a) 3-D N/C and coordinate measuring machine (CMM) programming for disks
10. Programming Automated Inspection Devices
    a) Robotic inspection devices
    b) Coordinate measuring machine inspection of case bosses using DMIS language
11. Programming Automated Devices
    a) Robotic deburring of turbine blades or disks
12. The Air Force Integrated Blade Inspection System for airfoils at San Antonio Air Logistics Center
13. The Air Force Retirement for Cause disk inspection system at San Antonio Air Logistics Center

R20802/20

3.3 PROVIDED ARCHITECTURE AND SOFTWARE FOR DATA EXCHANGE

When GMAP began, it was not certain that the software approach taken on the PDDI program was appropriate to support the GMAP requirements. The PDDI approach developed a prototype for a software architecture, which upon first examination, appeared to complicate the process of data exchange. The PDDI software had performance problems, and its overall merits were still being debated by the PDDI IRB. Also, during the development of the PDDI demonstrations, one of the CAD/CAM developers opted to bypass the use of the PDDI software completely and build a direct PDDI translator to/from their system using the same interface philosophy as IGES. However, once all the PDDI demonstration results were complied, it was obvious that those who chose to use the PDDI software were able to implement complete data exchange using the PDDI translator more quickly and more accurately.

Early in GMAP, a new approach was contemplated. However, the time and risk factor involved did not warrant exploring new alternatives. As the needs and requirements were being determined, it became more evident that the PDDI software, with some modifications, would be capable of satisfying our requirements. This decision was substantiated by our State-of-the-Art survey, which indicated that the PDDI approach was the best to pursue.

The GMAP/PDDI system components and software architecture are explained in detail in the GMAP System Specification (SS560240001U). However, it is important to understand how this architecture differs from the type of interfaces that were being developed for IGES.

Prior to PDDI and GMAP, the primary means of data exchange were through the use of IGES. Interfaces were created by writing a program which would interrogate the native database of a CAD/CAM system and create a file in the IGES file format. Likewise, using the IGES file as input, a file would be built in the native database of the CAD/CAM system. These interfaces were usually not robust enough to handle all possible IGES information. As pointed out in Section 1, the PDDI program determined that the existing IGES translators were less adequate than expected with respect to completeness and correctness of translation.

Under PDDI and GMAP, a set of software tools which provided a robust environment for this data translation was created. This software was implemented on various computer hardware platforms and operating systems to prove that it was flexible. It has been implemented, and successfully tested, on IBM TSO and VM/CMS, DEC VAX VMS, and SUN UNIX.

3.4 IDENTIFIED REQUIREMENTS FOR "PRODUCT MODELER"

In 1985, the majority of the CAD/CAM industry was still thinking along the lines of CAD models and geometric information. Only a few organizations had embraced the idea of PDD and product models that had come out of the PDDI program. As part of the GMAP contract, it was necessary to establish the minimum requirements of a Geometric Modeling System. In performing this task, it was determined that the requirements, and limitations, of a geometric modeling system were well understood. What needed to be investigated was the minimum requirements of a Product Modeler. This was accomplished and submitted to the Air Force as Appendix D of the GMAP System Requirements Document (SRD560240001U).

Upon closer review by the GMAP IRB, the Product Modeler Document was found to raise more questions than it answered. The Air Force and the GMAP team determined that a more rigorous investigation needed to be performed. This was accomplished under an extension to the original contract and was published as a separate technology transfer document, Functional Requirements of a Product Modeler (TTD560240001U). The document was written to convey to industry the concepts developed within GMAP, and provide an architecture for development of a product modeler system. It identifies modules of the system and the interdependence of these modules. The primary intent is to convey an industry-focused view on the concepts and requirements of a product modeler such that commercialization of this technology can respond to generic industry needs.

3.5 HEIGHTENED INDUSTRY TECHNOLOGY AWARENESS/UNDERSTANDING

The PDDI program resulted in the engineering community better understanding the needs of manufacturing. For the first time, a thorough analysis of the manufacturing needs for PDD was documented and discussed in an open forum with prime aerospace manufacturers including Avco, Boeing, General Dynamics, General Electric, Lockheed, and United Technologies. This resulted in a core group of industries, primarily airframe manufacturers, that understood the content of, and the need for, PDD.

GMAP enlarged this small core group by including the technology users and developers on the IRB. We included gas turbine engine manufacturers, airframe manufacturers, major gas turbine engine subcontractors, computer system manufacturers, and industry manufacturers outside of aerospace. Table 3-2 contains a listing of the IRB members and respective companies. This broad cross section of U.S. industry resulted in very lively IRB meetings. The IRB members provided direction as to the prioritization of needs, appropriateness of solutions, and soundness of technical content.

In addition to the 15 members, the IRB meetings were open to U. S. companies, Government agencies, and universities. Attendance at IRB meetings ranged from 40 to 100 people. This forum enabled transfer of the GMAP findings to numerous industries and organizations. It also resulted in the GMAP mailings list growing to over 200 recipients.

TABLE 3-2.

IRB MEMBERSHIP

Chairman Mr. George J. Hess Ingersoll Milling Machine Co.	**Members** Jim Hutto Intergraph Corporation
Secretary Jason (Jack) Lemon International TechneGroup Incorporated	Chris Klomp and Mike McClure Boeing Company
Members Robert Badgett ComputerVision Corporation	Robert Krakowsky and Stan Pickford Wyman-Gordon Company
Jack Conaway and Ulrick Flatau Digital Equipment Corporation	Don Manor Deere & Company
Calvin W. Emmerson Allison Gas Turbine Division	Robert L McMahon, Jr. General Dynamics
S. J. (Jeane) Ford International TechneGroup Inc.	Donald Moracz Textron M&MTC
Donald J. Gregory General Electric/AEBG	Chet Moutrie Control Data Corporation
	Ed Schumacher Avco Aerostructures Textron

R20802/20

SECTION 4

MAJOR ISSUES

4.1 NEED FOR PRODUCT MODELER

The GMAP software and schema were created to demonstrate proof-of-concepts and to assist the national effort in development of PDES as an American national standard. The intent was that production implementation would not occur until PDES was sufficiently developed. GMAP provided a learning tool for those involved to better understand the problems that would be associated with the eventual implementation of PDES. From the GMAP point of view, the readiness to implement is most severely constrained by one major technology shortfall — the unavailability of a product modeler.

During GMAP, the concept of a product modeler evolved. Simply put, a product modeler is a software tool that can be used to define "all" of the data necessary to describe, use, and share a product completely, accurately, and unambiguously. This differs from today's CAD/CAM systems, or geometric modelers, which typically only define the physical (geometric) shape of a product. Currently, there is no efficient software tool that will support the creation of a complete PDD model. PDES will define the specification for the information that needs to be communicated; it will not define, nor create, the software tool to actually build the models. Our recommendations on the development of a product modeler are outlined in Section 5.3

The GMAP component software that is deliverable under the contract is not dependent upon the development of PDES. In fact, this software was installed at NIST to support the testing of PDES as it evolves. The software will be used as a baseline and can be modified, as needed, by the PDES Inc. organization to support the development of the PDES draft.

The GMAP-to-RFC and GMAP-to-IBIS Interfaces were also deliverables under the contract. These Interfaces are production worthy and are constrained in that they need PDD models in GMAP format. The prototype GMAP Interfaces can be modified once PDES is available so that PDD models can be supplied in the standard neutral format. To date, the GMAP-to-IBIS Interface is being used in a semi-production mode. Pratt & Whitney has supplied four additional blade models (from four different stages of the F100 engine compressor) to SA-ALC for use in IBIS. No plans for the GMAP-to-RFC Interface have been developed.

The remaining interfaces built to support the proof-of-concept demonstration are not being pursued at this time. As previously stated, the lack of a product modeler prevents the efficient creation of the needed PDD models. Presently, the cost of manually creating the models is prohibitive. Driven by the need to cut costs and lead times, we find the corporate culture ready to embrace PDD technology. While we work with the system developers and the rest of industry to develop software tools (product modeler/PDES), the GMAP concepts of PDD part models are being incorporated into the strategic planning of future production systems.

4.2 OTHER BARRIERS TO IMPLEMENTATION

In addition to the lack of a product modeler, there are a few technical issues that stand in the way of total implementation. These issues need to be addressed in a cooperative industry setting involving system suppliers and the users. There are basically four areas of concern.

1. There is a fundamental technology shortfall that requires research and development.

2. Product data transfer exchange capabilities are in a highly dynamic and evolving environment, which makes implementation and standards extremely difficult to manage.

3. Product data transfer must be addressed in light of the entire life cycle, introducing integration challenges.

4. Special DoD requirements compound the general industry requirements.

4.2.1 Technology Shortfalls

- Lack of full product description databases (and database management systems) — The database structures to represent and manage product data have not been totally defined. The database software to manage these structures are still in prototype mode. Product Definition Data Interface (PDDI)/GMAP is representative of this capability. The electronic versions of engineering drawings do not include all the data necessary for all the applications throughout product life cycle operations to be able automatically to use that original drawing.

- Lack of a full product modeler — The solids modelers that exist today do not allow a user to enter everything necessary to generate full product description databases. Today's modelers are good at creating geometry and topology, but fail to provide computer sensible information such as tolerancing, features, and notes. Input to the database is currently a significant technology barrier.

- Shortfalls in applications ready to use PDD — Since there is a lack of full product description databases, there are very few existing applications capable of using such a database.

- Lack of configuration control capability — There is a need for better traceability of product design releases. Current product designs, as well as designs of mature products, and their revisions, must be retrievable and accurately associated among operations within an enterprise. There is a great deal of manual verification currently taking place.

- Lack of PDD communications network — Today's communication networks are not designed to handle the massive amount of data present in a sophisticated computer file containing full product descriptions. Limited or condensed product descriptions are currently transmitted. Magnetic tape systems are not effective for rapid and frequent exchanges.

- System performance/workstation functionality — More advances are needed in workstation speed, power, and compression techniques to store large amounts of data.

- Proprietary database security — In many cases, prime contractors are allowing subcontractors direct access to product descriptions and internally developed application software. The activity could be increased if effective methods were developed to control who is allowed to access data systems and who is allowed to manipulate accessed data or software.

4.2.2 Dynamic Environment

In addition, product data exchange capabilities are in a highly dynamic and evolving environment which makes implementation and standards extremely difficult to manage. The issues that illustrate this problem are:

- Numerous levels of implementation — The current standards, such as IGES, are not implemented to the same extent by CAD/CAM system developers. Data conversion from one system to another can thus become very time consuming and error prone. Also, companies differ in the degree to which they commit to this technology.

- Technology in rapid state of change — Today, state-of-the-art systems can become obsolete quickly. For this reason, some companies wait for the system that is the "best" system for them. Others are continually experimenting with new capabilities.

- Overlapping technologies — Currently, companies are installing systems, such as optical disk systems, to automate the storage, retrieval, and archiving of drawings. These systems require communication networks, specialized terminals, computers, and so on. In parallel to this, companies are also attempting to integrate their CAD/CAM systems for the use and manipulation of intelligent drawings. Again, these systems require communication networks, specialized terminals, computers, and so on. In most cases, only a small percentage of the hardware/software environment is common to both implementations. This creates problems in financial justification, training, establishing operational procedures, and so on.

- Dual manual/computerized environment — Manual systems do not change to a totally computerized system overnight. Companies have to keep both systems going while they are transitioning and pay an operational cost penalty in the transition.

- Standards for a rapidly evolving technology — The IGES/PDES efforts are attempting to standardize a technology that is not yet developed. The PDES effort is more of a R&D activity than a standardization effort.

- Education/training gap — Employees throughout an enterprise must be trained not only how to use product data generation, manipulation, and transfer equipment but also how to use it efficiently and effectively. Employees must learn that failure to look at the overall control requirements of the system may result in problems later in the product life cycle. Employees in the life cycle range from those with great expertise in using computers to those with no computer-based knowledge.

4.2.3 Integrated Approach

Other issues deal with the need of product data exchange to be addressed in light of the entire life cycle, introducing integration challenges.

- Heterogeneous computing environment — Users are not all going to acquire one single system. There is not one single solution to all product data transfer problems. Different computer systems will prevail among companies and the challenge becomes one of integrating these systems, hopefully, to the degree that it becomes transparent to the user.

- Nonstandard representations of data — There are various ways of creating a specific geometric feature, such as a spline, among system developers. As a result, product data transfers are sometimes impossible; other times, the accuracy is uncertain.

- Turnkey systems not adaptable — Many available systems do not meet the specific needs of many companies with unique product lines. Also, they are not easily adaptable to meet the company's unique needs or the company is not large enough to employee the resources necessary to modify such a system. On the other hand, many companies that acquire such systems and modify them to fit their unique needs discover that their system is no longer compatible with others of the same manufacture.

- Full life cycle coverage — Single product databases that can be used by the many islands of automation in the life cycle of a product do not exist. Numerous translators are required to provide product data transfer effectively among the many life cycle operations. Translations are considered deficient for many applications.

- Interface to application software — Existing application software can generally use the databases that are now available. However, as we move toward the use of full product description databases, we will be required to develop new interfaces to these existing applications. But, we will also have the opportunity to automate life cycle applications that previously needed a more complete database.

- Feedback to design — Existing iterative design cycles do not always provide the designer with the information required for accurate decision-making early in the design process. Advances in product data transfer technology will provide more opportunities for effective feedback of information to the design process.

4.2.4 Special DoD Requirements

Special DoD requirements compound the general industry requirements.

- Methods of handling classified and proprietary rights data — For reasons of security, there is a need for companies that deal with defense contracts to control access to certain databases while they allow direct access by suppliers or dual source manufacturers to other databases.

- Applications in Air Logistic Centers (ALCs) — ALCs will be increasing their use of product data transfer applications to help reduce maintenance costs of weapons systems and to enhance the benefits of dual sourcing. The greatest benefits will come, again, from the use of full product descriptions.

- High-risk designs — Weapons systems are by nature frequently at the leading edge of technology. This requires product data exchange to be adaptable and flexible in encountering new and previously unknown configurations and products. Implied is the extra DoD need to accommodate rapid change in the product cycle.

SECTION 5

FUTURE CHALLENGES

Section 4 discussed the technical issues impeding product data transfer. As the first step in addressing these issues, efforts need to be initiated or continued in several areas directly related to the GMAP work. These areas are:

- Development of a complete specification for PDD
- Standards for the representation of PDD data
- Development of a product modeler and the standardization of the components of a product modeler
- Integration of PDD with other corporate databases/knowledge bases
- Integration of PDD with supplier base.

5.1 COMPLETE SPECIFICATION FOR PDD

GMAP focused on the PDD needs and requirements for turbine blades and disks. This work must be expanded to include all part types and all applications. The current CALS MIL-D-28000 (for IGES), PDES Inc. efforts to define Context Driven Information Models (CDIM), and the IGES/PDES organizations activities to define application protocols are all attempts to address this shortfall. These efforts are aimed at defining the information content required to fully support specific application areas. The expectation is that the sum total of these information packages will result in a specification that will completely address PDD throughout the total life cycle.

More work needs to be accomplished to address each application area within the life cycle. We recommend that the Air Force, and other Government agencies, continue funding NIST to head the coordination for the development of PDES. We further recommend that NIST be funded, in cooperation with PDES Inc., to work with the Government Interagency PDES Group in creating a composite listing of all application areas throughout the life cycle. The listing could be correlated by industry to create a matrix that can be prioritized. This will allow the development of the PDES specification in logical steps by:

- First creating a core information model that is chartered to support weapons systems
- Secondly, providing a global map for the expansion of this core to encompass and support the information needs of all applications across all industries.

5.2 ESTABLISH STANDARDS FOR PDD REPRESENTATION

Explicit in a complete PDD specification is the standard for its representation. Adherence is necessary to avoid costly, error prone, and often computer-intensive translations. The PDES and IGES communities have continually wrestled with the specification of standard mathematical representation of geometric data; in particular, for splined curve and surface entities.

Agreement and standardization are inhibited by the fact that many corporations have made significant investments in commercial and in-house systems that predate current standards activities. The cost of conversion to a single standard may be prohibitive. This cost factor, coupled with the realizations that no single representation is sufficient for all needs, and that new mathematical techniques and representations are continually evolving, present a challenge for commonality and standardization. We recommend that the PDES community work with the appropriate standardization organizations to issue recommended practices, parameterizations, standard word lengths, and guidelines for the use of geometrical PDD. The guidelines need to be included for each of the application protocols and they must encompass different part families such as turned parts, machined, sheet metal, composites, and electrical components.

Within each part family, there are optimal geometric modeling techniques and mathematical representations. To enable the user community to embrace and properly use PDD, we recommend that a standard computer sensible data dictionary be made available.

5.3 DEVELOP PRODUCT MODELER

Current CAD/CAM systems in the aerospace industry do not support the ability to provide complete PDD part models. These systems provide only the shape (geometry and topology) information and very little of the nonshape information that is needed. In fact, until the GMAP effort, information such as inspection zone information needed for logistics, had never before been represented in digital format as PDD.

GMAP used a rudimentary editor to supplement existing CAD/CAM systems to create this additional information. This was adequate to provide support for proof-of-concept demonstrations and to continue our support of the F100 models needed by IBIS. It is not a method that is desirable to use regularly on a production basis. The ability is needed to create full product models much the same way that we use CAD/CAM systems today. Based on the GMAP experience in creating the original GMAP PDD models, the baseline requirements for a product modeler were documented. The product modeler document outlines the technology voids of today's CAD/CAM systems and is a guide to assist CAD/CAM system developers in understanding industry's needs and requirements. It is anticipated that system developers will use this document as a baseline to create system specifications that can be used to develop the next generation of CAD/CAM systems — product modelers.

Industry and Government must continue to work closely with system developers to ensure that manufacturing industry needs are addressed in the new products that are being developed. We recommend that a project be funded that will define a framework for the development of related standards that must be defined. A time table, consistent with the CALS objectives, must be established and work begun on the development of the needed specifications.

5.4 INTEGRATE PDD WITH OTHER DATABASES

There is a growing national awareness that information must be managed and, that for information to be useful, it must be transformed into knowledge. Today, computerization in industry has resulted in "Islands of Information" that reside on a multitude of hardware and software platforms. This information is not easily accessible and is, therefore, not available to be shared throughout an enterprise. To enable these databases to be shared between locations, applications, and systems, they must be integrated. Several Government and industry initiatives are already underway to help resolve the task of integrating existing corporate databases.

GMAP studied the problem of integrating the information needed to define a product, that is PDD. As a result of this work, a system architecture was prototyped that provided a mechanism to communicate and share PDD across life cycle boundaries. The next step is to add the GMAP concepts on the integration of PDD to the efforts of integrating the business data of an enterprise. To this end, we recommend the funding of programs such as OLIS (On-Line Information System) that will address the integration problems through focused research and development. Research is needed to address the fundamental technology shortfalls that exist in areas, such as:

- Open architecture
- Networking
- Database management system support for PDD
- Knowledge representation of product and process data
- Parallel processing
- Expert systems and databases
- Distributed technology.

To be successful, it is recommended that system developers be strongly encouraged to participate so they will develop ownership of the ideas and concepts that result from this research and be appropriately motivated to develop commercial products.

5.5 INTEGRATE PDD WITH SUPPLIER BASE

The small and medium sized companies, those who are suppliers to the prime aerospace contractors, must be fully integrated into the dataflow. Until corporate databases are more fully integrated, only small inroads can be made in integrating the supplier base. In the interim, it would be very productive to educate these companies on the impact that this integration and dataflow will have on their businesses. They will need this understanding to invest wisely in the types of computer hardware and software. They will also need the appropriate people to support their businesses in the future. These will not be easy to obtain.

We recommend that a program, similar to the Machining Initiative for Aerospace Subcontractors (MIAS), be funded to study supplier companies and determine the needs, requirements, and most of all, the benefits to be gained from the use of computerized data in an integrated network with the prime contractors.

We also recommend that the supplier IMIP programs include assistance to suppliers for computerizing their factories to facilitate the interchange of data.

Further, we recommend that the current NIST efforts to transfer the AMRF results to mid- and small-sized business through the Manufacturing Technology Centers Program be coupled with the above mentioned "MIAS-like program." This would focus the efforts that are trying to reach the backbone of American industries, the small-to-mid-size companies, and encourage them to step up to the needed modernization.